# ‡2 Vast Eclipse Cycles: Stabilities & Gaps

## Delicate Huge Eclipse Cycles' Six-Century Pulsations

## Ancients' Longest Period-Relation? — 1325 Years

## Ptolemy Now Connectable to His 3277 Month Cycle

## Greek Use of 13th Century BC Data: Yet Another Hint

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## A The 3277 Month Cycle & Our Expanding Temporal Horizon

**A1** *DIO 6* ‡1 §E investigated Ptolemy's last lunar equation (*Planetary Hypotheses* 1.1.6 or Rawlins 1996C [www.dioi.org] eq.10):

$$3277^{\mathrm{u}} = 3512^{\mathrm{v}} \qquad (1)$$

(Superscripts here & below: u = synodic months, v = anomalistic months, w = draconitic months; g = anomalistic years, y = tropical [Metonic][1] years, $y$ = sidereal years, K = Kallippic years; d = days, h = hours, m = timeminutes. Degree-remainders merely signify 360ths.)

**A2** In Rawlins 1996C (eq.11), we found that tripling eq.1 produced an eclipse cycle:

$$9831^{\mathrm{u}} = 10536^{\mathrm{v}} = 10668^{\mathrm{w}}1/2 + 22^\circ = 795^{\mathrm{g}} - 65^\circ = 290315^{\mathrm{d}}07^{\mathrm{h}} \qquad (2)$$

It was there discovered that this would require eclipse data from no later than the 9th century BC, $84^{\mathrm{y}}$ before Nabonassar 1 (the long overconfidently[2] assumed 747 BC limit for Babylonian astronomical observations later used by the Greeks). But DR did not then go beyond, since the very idea of Greek access to pre-1000 BC data seemed just too outré.

**A3** But since *DIO 11.1* (Rawlins 2002B & Rawlins 2002H), we have consistent indications (esp. Rawlins 2002H §§C9&D1) of Greek use of 13th century BC eclipses. So, on 2003/1/26, while walking along Baltimore's University Parkway, the *DIO 11*-triggered afterthought (finally. . .) arrived: I'd never checked multiples of eq.1 beyond three; so I swiftly tried out higher ones — and immediately (17:20 EST) found that five times eq.1 hands us the following eclipse-cycle:[3]

$$16385^{\mathrm{u}} = 17560^{\mathrm{v}} = 17781^{\mathrm{w}} - 23^\circ = 1325^{\mathrm{g}} - 109^\circ = 483858^{\mathrm{d}}19^{\mathrm{h}} \qquad (3)$$

[1] See Rawlins 1996C fn 13.

[2] See Rawlins 2002B fn 7.

[3] In reality, eq.3's 2nd term was $17560^{\mathrm{v}} + 4^\circ$. (See eq.10.) Eq.3 adds yet another eclipse-cycle to *DIO*'s collection thereof (fully listed at §F7), which we have reconstructed just out of simple multiples of anciently-attested lunar period-relations. Rawlins 2002H §E3 (or, better, fn 17's large parenthesis) found it improbable — at a moderately significant level — that so many eclipse-cycles could thus arise merely by accident. However, the fact that eq.1 leads us to more than one eclipse cycle (eqs.2&3) does not increase these odds, since the computation of each cycle's likelihood (of having possible-ancestor-eclipse-cycles) was found by asking merely for the probability of non-zero potential ancestors.



**A4** This 1325 yr cycle is comparable in delicacy to the 690 yr cycle (§E5), the 795 yr cycle (eq.2) and the 1010 yr cycle (Rawlins 2002B eq.2) for a reason common to them: in each of these four cases, the absolute magnitude of the [mean] draconitic remainder $r_{\mathrm{W}}$ (23°, 23°, 22°, & 22°, resp) is so near the [true] 25°– outer limit for eclipse-pairs occurring at all, that for each of these cycles the odds are merely ordmag 1/10 that a given eclipse will have a previous cycle-mate.

**A5** Either eq.2 or eq.3 — or possibly both (§D2) — could have launched eq.1. Already in Rawlins 1996C §§D-H, the case for eq.2 has been presented; now, we will proceed below to investigate the pro-eq.3 evidence, e.g., §§B, C, E3, fnn 5&6.

## B Which Cycle Was Ptolemy's Final Lunar Equation Based Upon?

**B1** There is a remarkable feature common to all four of §A4's long&delicate cycles ($690^{\mathrm{y}}$, $795^{\mathrm{y}}$, $1010^{\mathrm{y}}$, $1325^{\mathrm{y}}$): each exhibits gaps during which no eclipse-pairs occur. (Note: such unfragile relations as the key $345^{\mathrm{y}}$ cycle [§F7] have no gaps at all.) We will discuss details later (§F4). But the immediate connexion is this: the $795^{\mathrm{y}}$ cycle's classical-era gap [zero eclipses with mates $795^{\mathrm{y}}$ earlier] extends from −36 to +254, while Ptolemy's writing of the *PlanHyp* (containing our sole attestation [§A1] of eq.1) was about 160-170 AD. By contrast, for our newly-proposed $1325^{\mathrm{y}}$ cycle: the classical periods when no eclipses occur (which have prior umbral eq.3-mates) are (§F6) −262/1/26 to −193/5/11 and +331/3/10 to +393/5/12.

**B2** Now, it is generally believed (and Rawlins 2002B §L4 bolsters the conventional view) that *PlanHyp* (source of eq.1) improves the theories of the *Almajest* by using data from Ptolemy's own time. If this theory is on the right track, it starts us in the direction of favoring eq.3 as eq.1's (prime) basis — for the obvious reason that no eq.2-separated eclipse-pairs ended during Ptolemy's career, or indeed for well over $100^{\mathrm{y}}$ before he was even born (§B1). By contrast, eq.3-pairs repeatedly occurred (§E2) during his century.

## C Ptolemy's Era Connectable to 3277 Month Cycle After All

**C1** And it gets only better when we check in detail. An eclipse which has a mate (another umbral eclipse) $16385^{\mathrm{u}}$-distant must be a partial eclipse of magnitude less than 10 digits. Of Ptolemy's four eclipses (*Almajest* 4.6&9), the only ones of sub-10-digit magnitude are those of 125/4/5 & 136/3/6. By a striking coincidence, each has a mate $16385^{\mathrm{u}}$ before (and visible in Babylon): −1200/7/11 & −1189/6/12, respectively. How *a priori*-unlikely is this? We will evaluate the odds in two ways.

**C2** Approach 1: During the period of Ptolemy's contemporary observational data (125-141), sixteen lunar eclipses were at least partially[4] visible in Egypt, of which Ptolemy used four. The probability $p_1$, that these four eclipses should include the only two that had prior eq.3-mates, is:

$$p_1 = C_2^4/C_2^{16} = 6/120 = 1/20 = 5\% \qquad (4)$$

**C3** Approach 2: During the years 125-141, seven sub-10-digit eclipses were visible in Egypt, only two of which had previous eq.3-mates. The probability $p_2$ that both happen to be the very two which Ptolemy preserved is:

$$p_2 = 1/C_2^7 = 1/21 \approx 5\% \qquad (5)$$

**C4** Either way, the odds (though not huge) are statistically significant, and this in a pure probability case — i.e., where the gauging of degree-of-significance is not muddied by the nonGaussian vagaries which typically attend observational error.

[4] See Rawlins 2002B fn 10.

## D But What of the 795 Year Cycle?

**D1** So does the case for eq.3 now overturn Rawlins 1996C's belief (esp. §E) that eq.2 underlay eq.1? It very well may. However, one's view of this question depends in part upon whether one accepts that eq.1 had to be new for Ptolemy to cite it. (Not the firmest basis of argumentation.) After all, it is possible (if not probable) that eq.1 arose from both eqs.2&3.
**D2** Though obviously we now have a strong case that eq.1 originated in Ptolemy's era, the foregoing is not a rigid bar to Hipparchos having known of eq.1, too. Several eq.2-eclipse-pairs were available to him; and, for using eq.2, he would require eclipse data only back in the 10th (not 13th) century BC. (In eq.2's favor, see also Rawlins 2002B §G & Rawlins 1996C §I15 item [d].) Further, paralleling Ptolemy's coincidence (§C1): the only Hipparchos partial lunar eclipse (−140/1/27) happens to have a prior eq.2-mate (−935/3/26) — though (see fn 5), if current estimates of Earth-acceleration are correct, it ended before moonrise in Babylon (while partly visible ordmag $10^\circ$ of longitude to the east thereof). (No Hipparchos eclipse has a previous eq.3-match, which is consistent with our general theory that classical-era astronomers were not using data older than the 13th century BC.) So all 3 extant small eclipses of Hipparchos & Ptolemy are connectible to the $3277^{\rm u}$ cycle (eq.1), an impressively big-stretch coincidence, given the eclipse-pairs' infrequency.

## E Implications

**E1** *In toto*, the foregoing obviously favors eq.3 as the source of eq.1, but it also requires Greek access to such early Babylonian data that the genetic-conservatives (who've long ruled ancient-astronomy-history's petrified landscape) may find eq.3 even less palatable a progenitor than eq.2. But, if one responds receptively to the pro-eq.3 evidence of §B, the implications are more unsettling and important than those of Rawlins 1996C's theories (which assumed eq.2-ancestry). [See below at §H.]
**E2** As noted at §B2, eq.1 appears to be based upon eclipse-pairs ending in the 2nd century AD — and (according to eq.3) with separation $1325^{\rm y}$. Thus, since eq.1 could not have been later than c.165 AD (§B1), simple subtraction tells us that eq.1 was based upon eclipse-pairs whose early eq.3-mates were no later than:

$$165 - 1325^{\rm y} = -1160 \tag{6}$$

— an era far earlier than the 'til-now conventionally-assumed limit (747 BC: §A1) for eclipse records that could have survived into classical antiquity. We've already seen (§C1) that Ptolemy's small eclipses both have eq.3-matches that occurred shortly before eq.6's date: Babylon-visible eclipses in −1200 & −1189. Moreover, several other eclipses that were recent to Ptolemy were matched by Babylon-visible eclipses $16385^{\rm u}$ earlier. (Note: all $16385^{\rm u}$-cycle eclipse pairs are from ss whose Meeus & Mucke 1992 numbers differ by 14.) We will list a few such pairs, also appending the two Ptolemy-eclipse matches:

| | | |
|---|---|---|
| −1247/7/22 | & | 78/4/16 |
| −1236/6/20 | & | 89/3/15 |
| −1207/5/31 | & | 118/2/23 |
| −1200/7/11 | & | 125/4/5 |
| −1189/6/12 | & | 136/3/6 |

**E3** Adding to Rawlins 2002B & Rawlins 2002H, the foregoing considerations represent the 3rd piece of *DIO*-produced evidence indicating that the astronomers of classical antiquity had access to 13th century BC (§C1) Babylonian eclipse records.
**E4** Note two revealing implications here: [A] The possibility considered in Rawlins 2002H (§D4 vs fn 14), that Hipparchos may have had *special* access to 13th century BC Babylonian data, is hardly compatible with the indication here (§E2) that astronomers of Ptolemy's time may have used a different set of eclipses (presumably from a publicly



accessible data-collection), going back to the same 13th century BC. [B] If eq.1 was based upon Ptolemy-era discovery of eq.3, then Babylon cannot have been the place of discovery, since the city of Babylon died out during the 1st century AD.
**E5** Eq.3 is the longest of all the eclipse-cycles (incl. on §F7's list) which *DIO* has proposed may have have been used by ancient astronomers for gauging celestial motions. (We here itemize those which exceed 2/3 of a millennium: $690^y$ [Rawlins 1996C §§D&E]; $781^y$ [Rawlins 1996C eq.31]; $795^{\rm y}$ [eq.2 & §D]; $800^y$ [Rawlins 1996C eq.20]; $1010^{\rm y}$ [Rawlins 2002B eq.2]; $1103^{\rm y}$ [Rawlins 2002H eq.3]; & now $1325^{\rm y}$ [eq.3]. These are included in the list at §F7.) Eq.3 therefore especially possesses the attractive long-period-relation advantage that errors of imprecise-return and-or of timing at either end (of the cycle's time-interval) will not have a devastating effect on a monthlength value based (in standard fashion) upon dividing the interval's length by the cycle's number of months, since the latter is, after all, $16385^{\rm u}$. For, after division by 16385, a one hour error at either end of the span will contribute an error (in estimating the moon's synodic motion) of less than one part in 10 million. I have previously (Rawlins 2002B fn 22) doubted whether the hour of an eclipse at so remote an era would be likely to survive, an attitude which may need re-evaluation (if we accept that eq.3 underlay eq.1) given the excellent choice Ptolemy made in selecting eq.1 as his ultimate ratio of the synodic & anomalistic months. [Note added 2004/3/20. If a remote eclipse's hour survived without exact date, ancients' previously-established tables may've fixed the latter.]
**E6** Another corruptor of the accuracy of any anciently cycle-induced celestial motion would have been anomaly-remainders $r$, which reflect imperfect integralities in a cycle and so cause variations in returns which ought ideally to be constant. An example is the $109^\circ$ size of eq.3's solar-anomaly remainder $r_{\rm g}$. From Rawlins 1996C fn 56, we have the amplitude $A_{\rm g}$ of the wave of variation (in the length of ancient eclipse-pairs) caused by $r_{\rm g}$:

$$A_{\rm g} \approx 2 \cdot 2^\circ \sin(|r_{\rm g}|/2)/m \approx 8^{\rm h} \sin(|r_{\rm g}|/2) \tag{7}$$

(where $2^\circ \sin v$ is the solar equation of center, and $m = 0^\circ.508/\text{hr}$, the mean lunar synodic motion). So, for $|r_{\rm g}| = 109^\circ$ (eq.3), we have amplitude

$$A_{\rm g} \approx 8^{\rm h} \sin(109^\circ/2) \approx 6^{\rm h}1/2 \tag{8}$$

**E7** There is a similar (if ordmag smaller) effect from the lunar-anomaly remainder $r_{\rm V}$:

$$A_{\rm V} \approx 2 \cdot 5^\circ \sin(|r_{\rm V}|/2)/m \approx 20^{\rm h} \sin(|r_{\rm V}|/2) \tag{9}$$

(where $5^\circ \sin v$ is the syzygial lunar equation of center). For $|r_{\rm V}| = 4^\circ$ (fn 3), this is:

$$A_{\rm V} \approx 20^{\rm h} \sin(4^\circ/2) = 1^{\rm h}- \tag{10}$$

not a major factor. For the $1325^{\rm y}$ cycle, the in-phase sum of $A_{\rm g}$&$A_{\rm V}$ (eqs.8&10) can be no worse than a little over $7^{\rm h}$. Such an effect might cause an error of a part in 1-2 million if one (extremal) $1325^{\rm y}$ pair were used — i.e., without the caution of averaging several pairs.
**E8** But even averaging is insufficient protection here, because an unrandom portion of pairs go missing (see likewise at Rawlins 2002B §B7). In fact, the average of eq.3-pairs' length for the five visible-visible pairs listed in §E2 was too high[5] by nearly $1^{\rm d}/4$ day[6] —

[5] By contrast, those $795^{\rm y}$-pairs uneaten by gaps tend to be *lower* (than eq.2's mean $d = 290315^{\rm d}07^{\rm h}$). During the last 1 1/4 centuries (before the long gap after −36), the dozen umbral eclipses with prior umbral eq.2-mates ($9831^{\rm u}$ ago) tended to have hour-remainders in $d$ (above the integral value $290315^{\rm d}$) which were about $3^{\rm h}$-$4^{\rm h}$ or $6^{\rm h}$-$7^{\rm h}$. The latter remainder will obviously much lower the odds of both eclipses (of a pair) being above the horizon. The unfavorable Hipparchan eq.2-pair cited at §D2 fell victim to a $7^{\rm h}$ remainder in $d$. For such and other bad-luck reasons: of the six umbral eq.2-pairs preceding Hipparchos' last known observation (−126/7/7), none were surely visible at both ends of the $9831^{\rm u}$ interval. Thus, the −921/12/12 & −126/10/15 firmly visible-visible eq.2-pair was the first for decades, which Hipparchos might have used, if: [a] he were still active, and [b] clear weather favored both observations.

[6] But this effect carries an important benefit (much favoring eq.3): on average, it enhances eq.3's $d = 483858^{\rm d}20^{\rm h}$ to a little over the integral value $483859^{\rm d}$. Thus, an Alexandria-visible eclipse's prior

which, again, could cause an overestimate of the synodic month's length (after dividing the pair's separation $d$ by 16385) by about a part in 2 million.

## F Long Delicate Eclipse Cycles' Patterns

In recent years, *DIO* has examined four huge delicate eclipse cycles (citations at §E5): $690^{y}$, $795^{y}$, $1010^{y}$, & $1325^{y}$. In doing so, we have discovered certain features common to all four, and these have physical as well as historical interest.

**F1** Several saros-strings (ss) are always simultaneously active, and long delicate cycles are woven of ss ends (grazing-eclipses). Cycle-pairs' lunar anomalies $v$ are usually spaced about 120° apart. When ss successively appear, disappear, & are replaced by new ss, delicate-cycle eclipse-pairs' anomalies tend (except during occasional transition periods) to be either very nearby or about 120° distant — an effect resembling a cinema of a variably-diffuse equilateral triangle.

**F2** For any given epoch, the $v$ at which a cycle's eclipse-pairs occur are near[7] the three points of this slowly precessing equilateral triangle, which we have already dubbed the "PBT"[8] while analysing it in Rawlins 1996C. Within each ss, the successive anomalies flow in retrograde at a mean speed of a little under 3°/saros or nearly a degree/$6^{y}$.

**F3** However, as each ss is replaced by succeeding ones (in the PBT cinema), the anomalistic triangle moves not backward at §F2's degree-per-$6^{y}$ pace — but rather forward at about a degree per $17^{y}$, a speed controlled by the lunar anomalistic precession of the highly accurate $441^{y}$ Hipparchan draconitic equation (*Almajest* 4.2; Rawlins 1996C §F10 & eq.19 [or Rawlins 2002H eqs.1&3]).

**F4** We have mentioned previously (§B1, Rawlins 1996C §F, Rawlins 2002B §B3) that our delicate long cycles are so fragile that (for all four) whole decades or even centuries will pass without a single umbral pair occurring. That is, during such a temporal gap, if an eclipse has a prior cycle-mate, it's penumbral & thus effectively invisible. For each of our four cycles, the mean periodicity of the occurrence of these gaps is roughly 6 centuries, an effect influenced by the near-integralities of a nest of secular lunisolar returns of about that length (inter-related by the saros & the $65^{g}$ cycle): $6667^{u}$ ($539^{g}$), $7248^{u}$ ($586^{g}$), $7471^{u}$ ($604^{g}$), $8052^{u}$ ($651^{g}$). E.g.,

$$7248^{u} = 7768^{v} - 82^{\circ} = 7865^{w}1/2 + 0^{\circ} = 586^{g} - 4^{\circ} = 214037^{d}18^{h} \qquad (11)$$

**F5** Of course, as noted in §F4, the period of disappearance (of umbral eclipses having earlier umbral matches, according to a cycle) does not occur with discrete suddenness. During fertile (i.e., non-gap) periods, the rate of pair-occurrence rises and reaches a maximum at about the halfway-point between gaps — and the average length of the intervals between the pairs themselves also reaches an extremum there. (And in the time just before&after a gap, the number of umbral pairs noticeably ebbs in comparison to the maximal density occurring halfway between gaps.) These extremal effects will combine to bias-corrupt any estimate of monthlength based upon naïve averages of data (as remarked at §E8 and Rawlins 2002B §B8), since pair-intervals' sizes reach the opposite extremum during a gap (whose intervals would of course be missing from the average's input, by the gap's very definition).

eq.3-mate eclipse will almost always have been visible (i.e., above-the-horizon) in Babylon, one hour to the east. This is one of the reasons why visible eq.3 pairs were more frequent than visible eq.2 pairs.

[7] The density of eclipse-occurrence is greatest for the anomaly-point (of the equilateral PBT's three points) which is nearest perigee, and it is least (indeed often virtually or exactly nil) for that which is nearest apogee.

[8] Precessing ss-Bound anomalistic-Triangle (Rawlins 1996C §F). (Some cycles [e.g., $690^{y}$] exhibit more than one PBT.) The PBT's advancement/gap is c.1/10 of the zodiac (a rate which increases very slightly over the centuries), so that after roughly 2 millennia, the three PBT points are advanced near enough 1/3 of a circle that the PBT is approximately as it was.



**F6** For the information of our readers, we here supply the dates of gaps for all four of our long delicate cycles; these gaps[9] indeed appear about every 6 centuries (§F4):

$690^{y}$: −788/11/12 to −386/ 4/15 and −111/ 7/ 2 to 254/11/12.
$795^{y}$: −683/ 9/23 to −357/ 9/19 and − 36/12/ 7 to 254/11/12.
$1010^{y}$: −830/ 2/ 4 to −548/11/29 and −244/ 2/ 7 to 67/ 5/17.
$1325^{y}$: −262/ 1/26 to −193/ 5/11 and 331/ 3/10 to 393/ 5/12.

**F7** It will also be useful to other ancient-astronomy investigators to provide $A_{\mathrm{g}}$&$A_{\mathrm{V}}$ for all of the long cycles *DIO* has discussed (delicate or no), including the $345^{y}$ cycle (whose minuscule $A$ values dramatically illustrate its superiority, thus explaining its adoption [Rawlins 2002A] as the best foundation for the mean month), its double ($690^{y}$ cycle), plus the famous $18^{y}$ saros and $19^{y}$ Metonic (Easter) cycle. We list successively each cycle's duration in synodic months $U$, as well as its integrally-rounded number of solar anomalistic years $G$, solar remainder $r_{\mathrm{g}}$, associated amplitude $A_{\mathrm{g}}$; lunar anomalistic months $V$, lunar remainder $r_{\mathrm{V}}$, associated amplitude $A_{\mathrm{V}}$; draconitic months $W$, & draconitic remainder $r_{\mathrm{W}}$:

| $U$ | $G$ | $r_{\mathrm{g}}$ | $A_{\mathrm{g}}$ | $V$ | $r_{\mathrm{V}}$ | $A_{\mathrm{V}}$ | $W$ | $r_{\mathrm{W}}$ |
|---|---|---|---|---|---|---|---|---|
| $223^{u}$ | $18^{g}$ | $+10^{\circ}1/2$ | $0^{h}3/4$ | $239^{v}$ | $-3^{\circ}$ | $0^{h}1/2$ | $242^{w}$ | $-0^{\circ}1/2$ |
| $235^{u}$ | $19^{g}$ | $-0^{\circ}1/4$ | $0^{h}$ | $252^{v}$ | $-53^{\circ}$ | $9^{h}$ | $255^{w}$ | $+7^{\circ}1/2$ |
| $4267^{u}$ | $345^{g}$ | $-7^{\circ}1/2$ | $0^{h}1/2$ | $4573^{v}$ | $-0^{\circ}5/6$ | $0^{h}1/6$ | $4630^{w}1/2$ | $+11^{\circ}1/3$ |
| $8534^{u}$ | $690^{g}$ | $-15^{\circ}$ | $1^{h}$ | $9146^{v}$ | $-1^{\circ}2/3$ | $0^{h}1/3$ | $9261^{w}$ | $+22^{\circ}2/3$ |
| $9660^{u}$ | $781^{g}$ | $-2^{\circ}+$ | $0^{h}1/6$ | $10353^{v}$ | $-92^{\circ}$ | $14^{h}$ | $10483^{w}$ | $-2^{\circ}1/3$ |
| $9831^{u}$ | $795^{g}$ | $-65^{\circ}$ | $4^{h}1/3$ | $10536^{v}$ | $+2^{\circ}1/3$ | $0^{h}1/2-$ | $10668^{w}1/2$ | $+22^{\circ}1/3$ |
| $9895^{u}$ | $800^{g}$ | $-2^{\circ}1/2$ | $0^{h}1/6$ | $10605^{v}$ | $-145^{\circ}$ | $19^{h}$ | $10738^{w}$ | $+5^{\circ}1/4$ |
| $12494^{u}$ | $1010^{g}$ | $+42^{\circ}$ | $3^{h}-$ | $13390^{v}$ | $-8^{\circ}$ | $1^{h}1/2-$ | $13558^{w}1/2$ | $-22^{\circ}$ |
| $13645^{u}$ | $1103^{g}$ | $+62^{\circ}1/2$ | $4^{h}+$ | $14624^{v}$ | $-173^{\circ}1/3$ | $20^{h}$ | $14807^{w}1/2$ | $-0^{\circ}$ |
| $16385^{u}$ | $1325^{g}$ | $-109^{\circ}$ | $6^{h}1/2$ | $17560^{v}$ | $+4^{\circ}$ | $0^{h}2/3$ | $17781^{w}$ | $-22^{\circ}3/4$ |

## G Reflections

I do not know with certainty whether others have previously explored all of the peculiarities and the variety of interacting periodicities & pulsations which we have here revealed, in connection with the peculiar class: delicate vast eclipse cycles. (The lengthy study van den Bergh 1955 anticipated none of our new results.) But I hope that these will be of interest both to astronomers and to historians — and that the latter will be assisted (by the foregoing scientific findings) in future analyses of ancient astronomers' methods.

[Note added 2008. *DIO 11.1* and *DIO 13.1* have found solutions to all three previously unsolved ancient lunar period-relations, adducing five eclipse-pairs. The condition that all ten eclipses be above the horizon for at least some portion of the umbral phase relates to $\Delta T$ researches. (Of the 5 older eclipses, 4 were near the horizon, possibly helping later astronomers know their hour.) $\Delta T$ for the 13th century BC has heretofore been exclusively based on an *extrapolative* leap. (Across a 1/2 millennium gulf between then & the earliest extant eclipse records, data elicited and analysed by dedicated experts, for whom *DIO* has high admiration.) By contrast, *DIO*'s triple-solution, a "mere" computational speculation, represents a *mathematical* leap, to an isolated, non-extrapolated 13th century BC snapshot. As noted, our method is Greek-standard-attested (and easily explains all 3 period-relations' integrality & high accuracy); but if firm incompatibilities between the two leaps develop, it will be up to *DIO* to snipelessly publish the other side and up to others to choose.]

[9] Some gaps are not entirely empty. The 1st of §F6's two $1325^{y}$ gaps contains two grazing eclipses: −233/7/2 & −215/7/12. The $690^{y}$ gaps contain grazing eclipses (over $100^{y}$ apart): −668/6/11 & −527/5/14 and 12/5/24 & 153/4/26.

## H Sparse-ReMotes vs Truckload-Beamers [Note added 2003/12/30]

By automatically rejecting the discoveries of the present paper — as well as Rawlins 2002B & Rawlins 2002H — purportedly on the basis that there are no remote 13th century astronomical records directly surviving, our glowingly self-satisfied Muffiosi invite the following ghastly mote-beam (Matt. 7.3-5, Luke 6.41-42) observation, which DR put forcefully to the world's top Babylonianists (2003/6/22), at the latest University of Notre Dame biennial history-of-astronomy conference: while a blank in 13th century BC records is perfectly understandable (given the rarity[10] of extremely early astronomical observations, as exemplified by the uniqueness of the even-earlier Venus tables of Ammizaduga),[11] no such excuse is at all possible to explain away the *total* absence (in extant Seleukid-era Babylonian cuneiform records) of any explanation of how "Babylonian" astronomical parameters & tables were arrived at, this for a period from which (unlike the 13th century BC) a truckload of astronomical-math cuneiform texts do survive. Such critical explanatory ancient texts we have in detail from our slim Greek astronomical-math heritage, where (by contrast to Babylonian) we occasionally can even discern theory-founding empirical methods in action (see ***especially*** Jones 1999A [or *DIO 9.1* p.2]) and can very precisely trace tabular parameters' empirical bases: e.g., Rawlins 2003J eq.31 & Rawlins 2002A eqs.6-13. Our utter blank in parallel Babylonian material is completely consistent with DR's long-loathéd position (Rawlins 1991W §§H3-H4 & fn 73) that *Babylonian astronomy is derivative*; but it is embarrassingly inconsistent with the sacred-central Muffia tenet that Babylonians were the true originators of serious ancient mathematical astronomy.

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D.Rawlins 2002B. DIO *11.1* ‡2.
D.Rawlins 2002H. DIO *11.1* ‡3.
D.Rawlins 2003J. DIO *11.2* ‡4.
Gerald Toomer 1984, Ed. *Ptolemy's Almagest*, NYC.

[10] Ptolemy alleges (Rawlins 2002B fn 7) that full *continuous* Babylonian astronomical records surviving into his (or Hipparchos') time start at 747 BC; yet, from the first few post-747 BC centuries very, very few now exist. So how can we use our admitted blank in 13th century BC data, to found trustworthy conclusions about the survival rate (down to Hipparchos' time) of such early Babylonian eclipse records? [I.e., if Hipparchos had access to about 100 usable Babylonian eclipse records from the centuries soon after 747 BC, then their survival rate (from his day to ours) has been ordmag 1%. So, if he had just 10 (perhaps bunched) pre-1200 BC eclipse data (could this explain ancients' resort to odd [gappy or perigee-apogee] eclipse cycles?), then it's c.10-to-1 against any such surviving today.]

[11] Obvious question: if a 15th century BC Babylonian astronomical text (Ammizaduga-Venus) — entirely unmentioned in extant classical texts — can survive about $3500^{y}$ (incl. the Dark Ages) down to the present, then: by what divinely-bestowed wisdom do Muffiosi conclude that it is impossible that unmentioned (nontrivially *later* than Ammiz) 13th century BC Babylonian astronomical material cannot have lasted merely about 1/3 as long? — down to the time of high ancient Greek astronomy. [Note added 2004/4/25. Mesopotamian gov't interest in astral prediction far precedes 747 BC: Eckart Frahm (Yale Univ) has kindly informed *DIO* that an 11th century BC astrologer's advice to his king is quoted by a 657 BC successor (*State Archives of Assyria 10* [1993 Simo Parpola Ed.] Letter #100).]